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MATHEMATICS.—*The symmetry of the autocatalytic curve.*[1] HARRY W. TITUS, Bureau of Animal Industry. (Communicated by JOHN R. MOHLER.)

It is now more than twenty years ago that Robertson started developing his autocatalytic theory of growth. His extensive investigations in this field, stopped only by his very untimely death, have been a direct stimulus to a large number of workers in biology and chemistry. At least in part, because of the acceleration he gave to the study of growth, the amount of work done in this field increased enormously during the last ten or fifteen years. As more and more work was done, it became apparent that the symmetric growth curve was the exception rather than the rule and modifications of the original autocatalytic equation, developed from different points of view[2,3] were proposed. Along with these proposed modifications some incorrect statements regarding the properties of the modified equations crept into the literature. It is the purpose of this paper to call attention to these statements and to demonstrate, mathematically, that they are incorrect.

A rather general form of the autocatalytic equation[4] is

$$\ln \frac{x + b}{A - x} = K(A + b)\,(t - t_1) \qquad (1)$$

or

$$\ln \frac{x + b}{A - x} = k(t - t_1) \qquad (1')$$

[1] Received June 28, 1930.

[2] ROBERTSON, T. B. Journ. Gen. Physiol. **8**: 463. 1926; **12**: 329. 1929.

[3] CROZIER, W. J. Journ. Gen. Physiol. **10**: 53. 1926.

[4] The more general form is:

$$\ln \frac{x \pm b}{A - x} = K(A \pm b)\,(t \pm t_1),$$

When b = 0, we have

$$\ln \frac{x}{A - x} = KA(t - t_1) \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

which is the form originally used by Robertson[5] and later by Brody[6] and others for describing the phenomenon of growth. More recently equation (1′) has been used by Robertson,[2] Crozier,[3] and others for the same purpose.[7]

All possible modifications of the general equation, (1), are symmetric about the point of inflection in the sense that either branch of its curve may be rotated about the point of inflection until it exactly coincides with the other branch. For all positive values of t_1, the point of inflection occurs to the right of the x-axis (here, the axis of ordinates) and when $t_1 = 0$, it occurs on the x-axis; it occurs above the t-axis (here, the axis of abscissas) when $b < A$, below when $b > A$, and at the origin when $b = A$ and $t_1 = 0$. (See Fig. 1.)

Robertson, on several occasions,[2] has referred to the curve of equation (1′) as being asymmetric in type. In the summary of his paper on the growth of normal white mice (1926) he says,

"3. The first and most extensive autocatalytic process is asymmetrical, being defined by an equation of the type:

$$\log \frac{x + B}{A - x} = K(t - t_1).$$"

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the sign preceding b being always the same in both terms in which b occurs. By the proper selection of the magnitude and sign of b and t_1, the point of inflection may be made to occur in any one of the four quadrants, or at the origin.

[5] ROBERTSON, T. B. *The chemical bases of growth and senescence.* 1923.

[6] BRODY, S. Journ. Gen. Physiol. **3**: 765. 1921; BRODY, S., and RAGSDALE, A. C. Journ. Gen. Physiol. **3**: 623. 1921.

[7] That the equations used by Robertson and Crozier are essentially the same, although the methods of developing them are different, is clear from the following:

If the differential form of Crozier's equation,

$$\frac{dx}{dt} = (K_1 + K_2 x)(A - x)$$

be written:

$$\frac{dx}{dt} = K_2\left(\frac{K_1}{K_2} + x\right)(A - x) = K_2\left(x + \frac{K_1}{K_2}\right)(A - x),$$

the differential form of Robertson's equation,

$$\frac{dx}{dt} = k\,(x + b)\,(A - x),$$

may be obtained from it by substituting k for K_2 and b for $\frac{K_1}{K_2}$.

And in a more recent paper, on sequence of growth cycles (1929), he says,

"It (equation (1')) also has the effect of rendering the cycle on either side of the moment of maximum growth velocity, unequal in slope and amplitude."

Snell,[8] in a foot-note to his paper on defects in the theory that growth rate is controlled by an autocatalytic process, says,

"In a later paper (Robertson, 1926) a different equation is used to permit a slightly asymmetrical curve, but it does not remedy this defect, or any of the other defects here discussed."

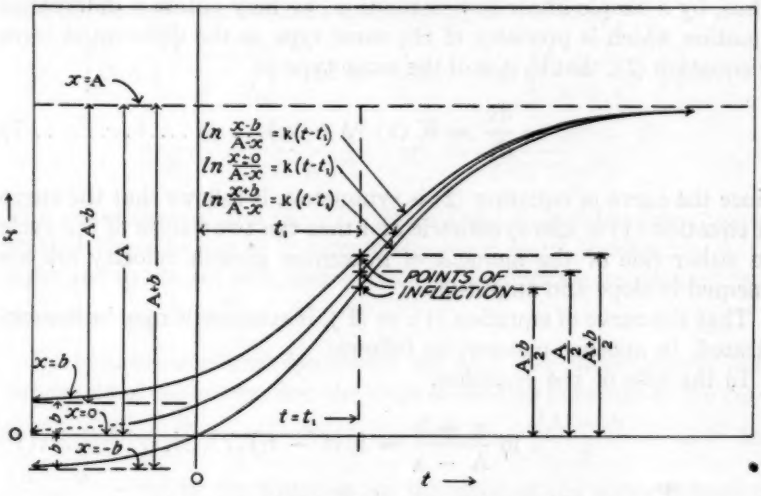

Fig. 1—Graphs of the autocatalytic equation,

$$\ln \frac{x + B}{A - x} = k(t - t_1).$$

N.B. The passing of one of the plotted curves through the origin is merely accidental; by proper selection of the magnitude of b, the curve may be made to cut the axis of ordinates above, or below, the origin.

As a matter of fact, are the two halves of the cycle on either side of the moment of maximum growth velocity unequal in slope and amplitude? Does equation (1'), or (1), define an asymmetric curve? A negative answer must be made.

[8] SNELL, G. D. Proc. Nat. Acad. Sci. **15**: 274. 1929.

Let us consider the differential form of equation (1), i.e.,

$$\frac{dx}{dt} = K\,(x + b)\,(A - x) \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

If we let $$x = x' - b, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

then $$dx = dx' \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

and on substituting (4) and (5) in (3) we get

$$\frac{dx'}{dt} = K\,(x')\,[(A + b) - x'] \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Thus, by a simple linear transformation, we may obtain a differential equation which is precisely of the same type as the differential form of equation (2), that is, it is of the same type as

$$\frac{dx}{dt} = K\,(x)\,(A - x) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Since the curve of equation (2) is symmetric, it follows that the curve of equation (1) is also symmetric and that the two halves of the cycle on either side of the moment of maximum growth velocity are *not* unequal in slope and amplitude.

That the curve of equation (1), or (1′), is symmetric may be demonstrated, in another manner, as follows:

In the case of the equation,

$$\ln \frac{x + b}{A - x} = k\,(t - t_1) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1')$$

it may be shown readily that the point of inflection is at $\left[(t_1), \left(\frac{A - b}{2}\right)\right]$. Now, if equal increments of abscissa (t) to the right and to the left of t_1 define values of x which are equidistant from the ordinate $\left(\frac{A - b}{2}\right)$, the curve is symmetric about the point of inflection. Such is the case, for when

$$t = t_1 + n,^{9} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

$$x = \frac{A\,\epsilon^{nk} - b}{1 + \epsilon^{nk}}, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

[9] n being any real number.

and when $$t = t_1 - n, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

$$x = \frac{A - b\,\epsilon^{nk}}{1 + \epsilon^{nk}}, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

and the distance between the ordinates of the curve at

$$\left[(t_1 + n), \left(\frac{A\,\epsilon^{nk} - b}{1 + \epsilon^{nk}}\right)\right] \text{ and at } \left[(t_1), \left(\frac{A - b}{2}\right)\right] \text{ is}$$

$$\frac{A\,\epsilon^{nk} - b}{1 + \epsilon^{nk}} - \frac{A - b}{2} \text{ or } \frac{(A + b)\,(\epsilon^{nk} - 1)}{2\,(1 + \epsilon^{nk})} \ldots\ldots\ldots (\alpha)$$

and the distance between the ordinates of the curve at

$$\left[(t_1), \left(\frac{A - b}{2}\right)\right] \text{ and at } \left[(t_1 - n), \left(\frac{A - b\,\epsilon^{nk}}{1 + \epsilon^{nk}}\right)\right] \text{ is}$$

$$\frac{A - b}{2} - \frac{A - b\,\epsilon^{nk}}{1 + \epsilon^{nk}} \text{ or } \frac{(A + b)\,(\epsilon^{nk} - 1)}{2\,(1 + \epsilon^{nk})} \ldots\ldots\ldots (\beta)$$

The quantities (α) and (β) are identical and thus it has been demonstrated that the curve is symmetric, since equal increments, to the right and to the left of t_1, define values of x which are equidistant from the ordinate $\left(\frac{A - b}{2}\right)$.

By suitable algebraic treatment we may also demonstrate, independently of the above, that the slope of the two branches of the curve is the same. If we substitute the ordinates $\left(\frac{A - b}{2} + m\right)$[10] and $\left(\frac{A - b}{2} - m\right)$ in the equation for the slope of the curve defined by equation (1), that is, in

$$\frac{dx}{dt} = \frac{k}{A + b}(x + b)(A - x) \ldots\ldots\ldots\ldots (12)$$

we get, in the first case:

$$\frac{dx}{dt} = \frac{k}{A + b}\left(\frac{A - b}{2} + m + b\right)\left(A - \frac{A - b}{2} - m\right)$$

$$= \frac{k}{A + b}\left[\left(\frac{A + b}{2}\right)^2 - m^2\right], \ldots\ldots\ldots\ldots (\gamma)$$

[10] m being any real number.

and in the second case:

$$\frac{dx}{dt} = \frac{k}{A+b}\left(\frac{A-b}{2} - m + b\right)\left(A - \frac{A-b}{2} + m\right)$$

$$= \frac{k}{A+b}\left[\left(\frac{A+b}{2}\right)^2 - m^2\right], \quad \ldots\ldots\ldots\ldots\ldots\ldots (\delta)$$

The expressions (γ) and (δ) are identical and thus it has been shown that the slope of the curve at any two points, which are equidistant from the point of inflection, is the same; and hence the slope of the two branches of the curve is the same.

Summary

Several incorrect statements regarding the curve defined by the autocatalytic equation,

$$\ln\frac{x+b}{A-x} = K(A+b)(t-t_1), \text{ or } \ln\frac{x+b}{A-x} = k(t-t_1)$$

have been made in the literature. These statements are to the effect that:

(1) the curve described by the above equations is asymmetric, and
(2) the two halves of the curve have unequal slopes.

It has been demonstrated in this paper that these statements are incorrect.

MICROBIOLOGY.—*Myxamoebae in soil and decomposing crop residues.*[1] CHARLES THOM and KENNETH B. RAPER, Bureau of Chemistry and Soils.

Amoebae are regularly observed and reported by students of soil organisms. Sandon in his book on Soil Protozoa and Waksman in his "Principles" reviewed the information available to 1927. Sandon supplemented the literature by summarizing the studies made at the Rothamsted Station. He made no reference to the amoeboid phase of the Myxomycetes and the Acrasieae as members of the soil population with characters sufficiently suggestive of protozoa to open the possibility of confusion. Brierley (1928 p. 16) listed five genera of Myxomycetes as occurring in soil with "evidence that they may live vegetatively in this habitat." Waksman in his "Principles", p. 236 refers to the Myxomycetes as including species which are plant para-

[1] Received June 17, 1930.

sites with the comment that they appear able to maintain themselves independently in the soil. Krzemieniewski reported that by proper culture methods many Myxomycetes may be obtained in culture from the soil. Harper, following Krzemieniewski's method, isolated *Polysphondylium* from soil collected in New York City parks. The extensive cultural studies reported by Olive and others have been primarily concerned with obtaining and identifying the fruiting bodies of this group of organisms. Very little has been reported to indicate the distribution and significance of the amoeboid phase or even the plasmodium phase of these organisms in the soil or in the decaying vegetation of the meadow or the cultivated field. We were surprised, therefore, to encounter these organisms in great numbers in the course of studies begun for entirely other purposes.

In December 1929, samples of decaying grasses and weeds were collected in an experimental field on the Arlington Farm of the United States Department of Agriculture. When brought to the laboratory, selected leaves and stems were cut into convenient lengths and dropped upon the surface of solidified mannite agar in petri dishes to permit certain saprophytic organisms present to develop. The nutrient medium used was free from nitrogen or nearly so, hence considered only as furnishing a moist substratum to favor the further development of organisms already present upon the grass.

Within a week several myxomycete plasmodia developed and moved about upon the agar in these plates. Thousands of amoebae or myxamoebae also spread upon the agar from pieces of decaying grasses and weeds. Masses of bacteria and mold mycelium covered and spread outward from every piece of decaying vegetation. Since we could find no record of observations of Myxomycetes under such conditions several series of such cultures were made to extend our knowledge of the presence and abundance of these forms under winter conditions in Washington and vicinity.

The first of these samples consisted of a few leaves of crab grass collected on February 6th from a roadside. Prior to this, the grass had been covered by snow for several days, and was quite wet when brought to the laboratory. The leaves were cut into convenient lengths and placed upon mannite agar in petri dishes and the dishes were held at room temperature. In the course of a few days, plasmodia were observed in all the plates. Large "amoebae" and small amoeboid cells, possibly myxamoebae, were present in considerable numbers; the latter were particularly numerous. Using a small sterile pipet, a part of one of the plasmodia was transferred on Febru-

ary 12 to a fresh mannite agar plate. To this culture was added from time to time a suspension of dead bacteria belonging to the *B. aerogenes* group. The plasmodium grew slowly but consistently until March 8th when it was transferred to hay infusion agar medium. By frequent transfers it is still in actively growing condition on this medium after four months. After the snow melted, samples of decaying grass were again collected from the field on February 8th. These samples were plated and incubated as before, and again in the course of a week plasmodia developed in all the plates. Two plates contained particularly well developed grayish-white plasmodia. These were more or less fan shape, measuring 4 cm. across the "fan," with stream of protoplasm extending back for several centimeters along the path, which the main portion of the plasmodium had recently traversed. One of these fruited on February 17th, producing about 150 sporangia which belonged to the genus *Didymium*. On February 18th a part of the other plasmodium was transferred to hay infusion agar and is still active in culture in May. The portion not transferred fruited two days later as a *Didymium*.

On February 17 wide mouth bottles of approximately one liter capacity were half filled with wet sand and sterilized. Samples of decaying grass from the field were placed on the sand in a rather compact mat three fourths of an inch in depth. By the end of the first week one of the twelve bottles thus prepared contained a visible plasmodium which climbed up on the side of the bottle. It was grayish-white in color and measured 1.5–2 centimeters in diameter. During the following week plasmodia were observed in two additional bottles. On February 27th, a few leaves from three of the bottles not containing visible plasmodia were dropped on mannite agar. Plasmodia developed in three-fourths of the plates. (See numbers 9, 12 & 13 in table 2). It was evident that the agar medium was not necessary for the development of plasmodia.

On February 20 (a warm period in 1930) the tobacco fields of the Bureau of Plant Industry and the University of Maryland, situated near Marlboro, Maryland, were visited. Various samples were collected. One mass of decaying annual grasses and the soft soil down to about 10 cm. and totalling perhaps 1 liter was placed in a bag and brought to the laboratory where it was transferred to a covered dish about 25 cm. in diameter and 10 cm. deep without adding any water. In approximately one week a plasmodium moved up from this mass out upon the glass and spread over about half of the inside of the

glass cover. During the following night the fruit bodies of a species of *Didymium* were produced.

In other dishes numerous small plasmodia were produced and spread outward from pieces of grass, ragweed stems and stems of *Erigeron* collected from various tobacco plots, and scattered over mannite agar. In some dishes millions of small myxamoebae were seen and later fruited abundantly as *Dictyostelium*.

In these various plates, microscopic examination regularly showed many encysted as well as active myxamoebae. Microscopic mounts from the dry stems and leaves as brought to the laboratory showed many such cysts which appeared to be similar to those which developed from time to time in the cultures. From these observations it was evident that myxomycetes and allied forms are well represented in the tobacco fields of Marlboro.

In the samples collected and plated thus far, no attempt had been made to separate the standing leaves and culms from those lying on the soil. The question now arose as to whether the myxomycetes were present only in the basal portion of standing grass leaves and in leaves lying on the soil, hence protected against extremes of temperature and desiccation, or if they were also present in leaves standing several inches above the soil. And if present in both, what was their relative abundance in the two? To determine this point a series of samples were collected; the uppermost portion of standing leaves and those lying on the soil were collected and plated separately, the former type being designated by "A" following the sample number, the latter type by "B" following the same sample number. The first of these were collected on February 21st; other samples being taken at later dates. Plasmodia appeared in 70% of all plates prepared from "A" samples and in 67.7% of those prepared from "B" samples. A full account of these platings is given in table 1.

During the same period some additional "composite" samples were collected and plated. Plasmodia appeared in 71% of all plates prepared from these samples. A detailed account is given in table 2.

All the myxomycetes thus far isolated from decaying grass, and cultured as above until fruits were produced, belonged to the genus *Didymium*. Species have not been determined.

Steps were then taken to determine whether or not plasmodia could be obtained from the soil underlying the sod from which the grass samples had been taken. Soil samples from varying levels ranging from the surface to a depth of twelve inches were diluted with 10 cc.

of sterile water, and the resulting suspension streaked on mannite agar plates by means of a platinum loop. Four or five streaks, a single drop of the suspension being used for each, were made across a plate and two or three plates prepared for each sample. Twenty-seven

TABLE 1.—GRASS SAMPLES—STANDING AND THAT ADJACENT TO SOIL PLATED SEPARATELY

Sample No.	A. Grass erect		B. Grass on soil		Days after inoculation	Type of grass	Date of sampling	Remarks
	No. of plates	Plates containing plasmodia	No. of plates	Plates containing plasmodia				
2	2	0	2	1	12	Rye	Feb. 21	Rye stems. Last summer's growth
3	4	1	4	2	12	Orchard grass	Feb. 21	Samples 2 to 5 inclusive taken in very warm weather for Feb. Grass very dry
4	4	3	4	3	12	—	Feb. 21	
5	4	2	4	2	12	—	Feb. 21	
15	5	5	4	3	9	Bluegrass	Feb. 27	Samples 15 & 16 taken day after rain. Grass moist. Temperature high (Feb.)
16	4	4	4	4	9	Orchard grass	Feb. 27	
18	4	0	4	1	12	Bluegrass	Mar. 20	See #19 below
22[a]	2	2	2	2	14	Sedge	Mar. 22	Samples dry
23	3	3	3	3	14	Velvet grass	Mar. 22	Temperature rather low but not freezing
24	4	1	4	2	14	Orchard grass	Mar. 22	
25[b]	3	3	3	3	17	Bluegrass	Mar. 22	
26	5	5	5	3	17	Bluegrass	Apr. 11	Samples 26–29 inclusive. Taken following heavy rains. Temperature 60–70°
27	3	3	3	2	17	Velvet grass	Apr. 11	
28[b]	5	5	6	5	17	Bluegrass	Apr. 11	
29	4	2	3	0	17	Orchard grass	Apr. 11	
19	4	3	4	4	12	Velvet grass	Mar. 20	Samples 18 & 19 rather dry. Temperature 40–55°F.
	60	42	59	40				
	= 70%		= 67.7%					

[a] Sedge collected from west end of reservoir, sample dry when taken but had been covered with water during much of winter.

[b] Very heavy sod in each case.

samples from five "borings" were collected. The plates were examined after incubation at room temperature from ten days to two weeks. Amoeboids, amoebae or myxamoebae were found to be very numerous in all the samples, even those taken from a depth of twelve inches, but plasmodia developed from only two of the twenty seven samples.

One was obtained from a sample of earth collected at a depth of four inches underlying a blue grass sod on March 11th, and resembled closely the plasmodia of *Didymium* which we have in culture. The other was obtained about two weeks later from a sample taken at a depth of three inches underlying another blue grass sod in the same

TABLE 2.—GRASS SAMPLES (A. & B. NOT SEPARATED)

Sample No.	A. & B.		Number days after sampling	Date of sampling	Type of Grass	Remarks
	No. of plates	Plates containing Plasmodia				
1	6	5	12	Feb. 21	Rye-Compost heap	Rye cut last summer and thrown on compost heap. Samples taken from this heap
9	4	2	8	Feb. 25	Orchard and Bluegrass	Samples 9 and 10: Grass from Walker Hill placed in bottles half filled with sand 2–17–30. Set in greenhouse. Samples from these plated
10	3	0	8	Feb. 25	" "	
M8	6	4	12	Mar. 3	—	Grass collected from experiment station at Marlboro
12	2	2	9	Feb. 27	Orchard and Bluegrass	Samples 12 to 14 inclusive taken from bottles in greenhouse prepared as #9 & 10
13	2	2	9	Feb. 27	" "	
14	4	3	9	Feb. 27	" "	
17	4	3	14	Feb. 27	—	Sample taken day after rain. Temperature high for February
20	4	3	12	Mar. 20	Orchard grass	Grass rather dry. Temperature 40–55°F.
30	4	4	14	Apr. 23	—	Rather dry grass collected from roadside at reservoir, Arlington Farm
31[a]	6	4	14	Apr. 23	Sedge	Sedge collected from west end of reservoir. Samples dry
	45	32				
	= 71%					

[a] This sample gave heavy growth of azotobacter in all plates. Nematodes were more numerous than in other samples.

field. This plasmodium was not isolated; but in the original plate it resembled rather closely plasmodia of *Stemonitis*, which had been grown from spores in this laboratory for comparison. This *Stemonitis* plasmodium consisted of very close networks of delicate strands of colorless protoplasm.

Dictyostelium was obtained in similar cultures made from two plots of Leonardtown loam under experimental study in the greenhouse including one plot limed to pH 7.1 and the other with about pH 4.2. Cultures from six other plots in the greenhouse showed abundant amoeboids, but no myxomycete was positively identified.

Among the other experiments already performed, the effect of seasonal changes in temperature have been rather striking. The plasmodia in culture were not much affected by small changes of temperature, but have shown decided dislike for temperatures above 20–22°C. This was particularly evident during the latter part of April and the early part of May, when there was extremely warm weather. The plasmodia growing in the laboratory prior to this became less active and grew very slowly. During the following week this effect was even more pronounced. Plasmodia in most cases broke up into sclerotia and in many cases disintegrated quite completely. Those that were still viable were placed in an incubator with a temperature range of from 15 to 18°C. Within a very short time normal growth and activity were resumed. Subsequent culture experiments have been carried at both incubation temperatures with the forms in culture showing decided preference for the cooler condition.

In another series of studies, dilution cultures at 1 to 50, 1 to 500 and 1 to 5,000 were made to test the presence of protozoa in plots of land containing decomposing rye and vetch. In certain of these cultures, amoeboid organisms were predominant. Mannite plates were streaked from these tubes. Of 15 such cultures, one produced *Dictyostelium* and another produced plasmodia.

These observations are recorded to call attention to the presence of myxomycete amoeboids as part of the soil population. Experiments in culture of these forms and efforts to determine their function as part of such populations are in progress. Meanwhile search of the literature furnished little information on the occurrence of Myxomycetes in the soil, and no direct reference to the isolation of plasmodia from decaying vegetation under winter conditions such as described in this paper. The following references are worthy of note: Miller (6) working in the Johns Hopkins Medical laboratories obtained *Stemonitis* plasmodia as contaminants in protozoa cultures which were being grown in tap water to which had been added unsterilized hay. He then collected hay from various sources and again plasmodia were obtained. He expresses the opinion that "plasmodia are constantly present on hay in one form or another." Lister (5) in his monograph of the Mycetozoa lists dead leaves and twigs as the most

common substrate for members of the genus *Physarum*. Also of interest here are *P. fulvum* gathered in Colorado at an elevation of 11,000 feet on "living willow, growing in snow," and *P. vernum* which is frequently found in the Swiss Alps growing "on leaves and grass close to the melting snow." Krzemieniewski (4) working in Poland found *Dictyostelium mucoroides* "in almost all soils examined," and species of *Polysphondylium*, though rarely, in uncultivated soils.

In seeking current information several visitors were consulted and the cultures exhibited. Professor George W. Martin of the University of Iowa was shown these cultures but had no record of such observations. Professor Robert F. Griggs of George Washington University reported having often seen a myxomycete fruiting upon the grass in his lawn in summer but that he had made no further study. Professor J. B. S. Norton of the University of Maryland reported similar observations upon the University campus. Professor H. H. Bartlett of the University of Michigan told of plowing an area in the Botanical garden at Ann Arbor and seeing large plasmodia come out upon the surface of the plowed ground and looking "like pancakes scattered over the field." From these reports it is clear that a considerable number of workers have been familiar with the occurrence of these species in cultivated land.

Professor R. A. Harper in his recent paper upon *Polysphondylium* and in conversation about this work attributed the suggestion of his method of isolation to Krzemieniewski and on the basis of his own rediscovery of that species in soil from the parks of New York City, suggested that the amoeboid forms of myxomycetes would probably be found to account for many of the amoebae reported by soil workers.

CONCLUSION

In these experiments with soil from Arlington farm in Virginia and tobacco plots in Marlboro, Md., the myxomycetes have been found to constitute an active component of the micro-population in the decaying vegetation and in the underlying soil.

Myxamoebae and plasmodia were developed in the colder part of the season and have been found to grow better at 15 to 18°C. than at 20 to 22°C. Myxamoebae at least if not the more complex plasmodia were found abundantly upon all parts of the grasses and weeds taken from our experimental plots between December and May 1930.

Members of this group should be considered in surveying the types of microörganisms present in any soil population.

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PALEONTOLOGY.—*Discovery of Permo-Carboniferous vertebrates in the Dunkard formation of West Virginia.*[1] R. W. WHIPPLE, Marietta College, and E. C. CASE, University of Michigan.

On December 27, 1929 Mr. Goff Carder reported to Professor R. W. Whipple the discovery of certain bones at Portland, Jackson County, West Virginia. Professor Whipple visited the locality and determined the horizon to be the Upper Marietta sandstone, which is in the lower portion of the Dunkard. The Marietta sandstones, named by I. C. White[2] from their typical outcrop in the vicinity of Marietta, Ohio, are easily recognized in this area; and in the interval between the Lower Marietta sandstone and the Upper Marietta sandstone are shaly sandstones, shales and red clay (Creston beds). The bones are from the lower part of the Upper Marietta sandstone 130 feet above the railroad track over Skull Run. The specimen was in a soft clayey cross-bedded sandstone, carrying an abundance of large flakes of white and black mica, made up of small rounded grains of quartz and the whole weathering to a light brown color.

The site was in the center of an old road and the specimen had been partly destroyed by passing wagons. All material that could be recovered was collected and has been studied by Professor E. C. Case. The specimen consists of parts of the spines, centra and ribs of *Edaphosaurus cruciger* Cope. More than half of four spines have been pieced together; there are in addition two nearly complete centra of

[1] Received June 23, 1930.

[2] West Virginia Geological Survey **2**. 1903.

posterior dorsal vertebrae, two nearly complete ribs, and numerous fragments and short pieces of other spines and ribs. So much of the specimen has been recovered that the identification is certain. This discovery confirms the identification of a small fragment previously discovered at Marietta in the Creston beds horizon.[3]

In a visit by Professors Whipple, Case and Hussey, to the region on May 31, a stop was made at Limestone Hill, on the boundary between Wood and Wirt counties, about thirty miles south of Marietta on the road to Ravenswood, West Virginia. At this locality in the cuts along the new highway are fine exposures of the upper Dunkard rocks with a series of at least four distinct limestones in the upper horizons. The limestone at this locality was identified by I. C. White[4] as the Nineveh Limestone, which is one of the most important beds in the upper Dunkard, as it can be traced for many miles in the high ridges of hills in the region. It is not a well defined stratum, for it varies from one to five feet in thickness and is often separated into shaly and nodular layers. Ray V. Hennen[5] designates the three upper beds as the Upper Rockport limestone, Middle Rockport limestone and Lower Rockport limestone from the fine exposures developed near Rockport, Wood county, two and a half miles north; and in his section identifies the lower or fourth bed as the Nineveh limestone. These Rockport limestones are of only local extent, and after further field studies may be identified as phases of the Nineveh limestone.

The upper Rockport is a lens of limestone from one foot to eighteen inches thick. At the upper surface there are a few inches of sandy limestone filled with fragments of bone. Below this, or a phase of it, is a dark mud-shale with numerous fragments. The shale is so fragile that it could not be handled without preparation but there were identified in the field: *Pleuracanthus* (probably the form described by Stauffer and Schroyer as *Diplodus washingtonensis*); scales and teeth of fish, probably the *Paleoniscus* of Stauffer and Schroyer; vertebrae very similar to *Lysorophous*; vertebrae very similar to *Theropleura*; a few large teeth of a Pelycosaur like *Dimetrodon*; a small amphibian femur of the type of *Trimerorhachis*; and numerous fragments of plates from the head of a similar form.

[3] STAUFFER, C. R. and SCHROYER, C. R. *The Dunkard series of Ohio.* Bulletin 22, Fourth Series, 1920.

[4] U. S. Geol. Survey Bulletin No. 65: 33. 1891.

[5] West Virginia Geol. Survey, Report on Wirt, Roane and Calhoun Counties. 46 and 143. 1911.

A careful study of the material is planned and may lead to different conclusions, but it seems quite certain that the fauna is very similar to that previously described from near Danville, Illinois, and to that of the Permo-Carboniferous beds of Texas and Oklahoma.

BOTANY.—*A new species of* Calathea *from Panamá.*[1] C. V. MORTON, National Museum. (Communicated by WILLIAM R. MAXON).

The following species of *Calathea* was discovered by Dr. A. F. Skutch while engaged in research work at the experiment station of the United Fruit Company at Almirante, Panamá, and is based on ample material presented by him to the U. S. National Museum. The description is also drawn in part from field notes made by Doctor Skutch, who is planning to publish shortly an account of the morphology and method of unrolling of the leaves.

Calathea magnifica Morton & Skutch, sp. nov.

Large herb reaching a height of 5 meters; radical leaves 2-ranked, homotropous; petioles reaching about 290 cm. in length, the lower half sheathing, the upper half terete, 1.3–1.6 cm. thick, the callous body at its upper end 23 cm. long; lamina with the right half always innermost in vernation, gradually increasing in size until the plant matures, oblong, truncate at apex, slightly asymmetric, the largest 114 cm. long by 58 cm. broad, glabrous, the lower surface whitish with a thick layer of wax, this separating in large flakes upon drying: stem 110–150 cm. long, bearing two leaves, the first one with the blade equaling that of the radical leaves, the second reduced; sheath 30–56 cm. long, not or scarcely auriculate, pubescent with short, simple hairs; inflorescence of two groups of spikes, one group from the axil of each of the cauline leaves; peduncles of spikes in the axils of lower leaf 30–60 cm. long, of upper leaf 10–50 cm. long, flattened, often flexuous, pubescent (especially at apex), streaked with pale green and brown; primary spikes 7–9, secondary spikes often arising from the lowermost bract of a primary, subcylindric, 18–30 cm. long, 3.5–5 cm. thick, the bracts 16–20 or more, distichous but somewhat displaced by a spiral twist of the axis, thus forming two spiral series, leathery-chartaceous, broadly obcordate, 5–6 cm. long, 5.5–7 cm. broad, pale green streaked or washed with brown, sparsely pubescent outside, glabrous within; primary bractlets winged on the back, hispid along the wing; flowers in pairs, the two usually not developing simultaneously, 4.6 cm. long; sepals lanceolate, 9–10 mm. long; corolla tube 2.6 cm. long, lobes oblong, obtuse, 20 mm. long, 7 mm. broad, dark Corinthian purple; staminodium white, obovate, 1.5 cm. long, ovary naked, surrounded by a tuft of hairs arising from its base; capsule loculicidal, 1.7 cm. long, pink; seed 7 mm. long; aril lamellose, 5 mm. long.

Type in the U. S. National Herbarium, no. 1,409,622–3, collected at the research station of the United Fruit Company, Almirante, Panamá, April 20, 1929, by A. F. Skutch (no. 12).

[1] Published by permission of the Secretary of the Smithsonian Institution. Received June 15, 1930.

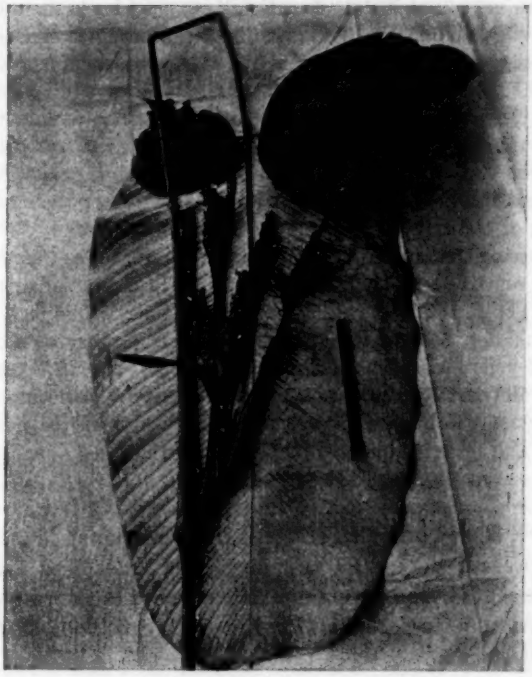

Fig. 1. *Calathea magnifica* Morton and Skutch. Inflorescence and leaf.

Fig. 2. Same, habitat view.

Dr. Skutch's field notes state that *Calathea magnifica* is the most abundant and conspicuous *Calathea* in the lowlands of the province of Bocas del Toro. It forms close stands in marshy places and at the borders of lagoons, and sometimes also in fairly well drained pasture land, but always in open places rather than dense jungles. It was in flower from January to June at least, but at the latter date the spikes were very old. At maturity the pedicel disintegrates, freeing the capsule, which then oozes through the plentiful slime coating the bracts and bractlets until it is exposed at the top, when it is burst by the swelling of the aril. The seeds are sought by birds.

It is surprising that such a large and beautiful species as *Calathea magnifica* could have remained so long undiscovered. Its closest alliance is with *C. lutea* (Aubl.) G. F. W. Meyer. This common Central American plant, which is usually smaller, has smaller spikes with fewer, bronze or reddish colored bracts, and yellow corollas. Related also is *C. insignis* Peters, a species smaller in all parts, having non-ceraceous leaves, glabrous, more widely spreading, closely imbricated bracts, and yellowish or whitish corollas.

In Fig. 1 the scale is indicated by the ruler, which is 30 cm. long.

BOTANY.—*Ten new species of* Passiflora, *mainly from Colombia and Peru.*[1] ELLSWORTH P. KILLIP, U. S. National Museum.

In the present paper ten new species of *Passiflora* are described, four of which are based upon material collected in the course of botanical exploration in Colombia and Peru recently carried on by the Smithsonian Institution.

Passiflora dolichocarpa Killip, sp. nov.

Stem subquadrangular, hispidulous; stipules semi-ovate, 6 to 7 mm. long, 2 to 3 mm. wide, finely hispidulous, especially at margin; petioles about 2 cm. long, slender, biglandular at or slightly below middle, the glands clavate, about 1.5 mm. long, 1 mm. wide, sessile; leaves hastately 3-lobed, 6 to 10 cm. long, 4.5 to 7 cm. wide (middle lobe lanceolate, acuminate, 3.5 to 4 cm. wide at base, the basal lobes reduced, short-acuminate), sinuate-dentate at margin, cordulate at base, membranous, finely hispidulous on both surfaces; peduncles in pairs, 3.5 to 4 cm. long, slender, articulate near apex; bracts semi-ovate, 4 to 5 mm. long, 3 to 4 mm. wide, oblique at base, sessile, irregularly lobed, hispidulous, borne at upper third of peduncle; flowers about 2.5 cm. wide; sepals oblong, 10 to 13 mm. long, 7 to 8 mm. wide, slightly cucullate at apex, hispidulous without, white, longitudinally streaked with red or purple within; petals oblong, 8 to 10 mm. long, 3 to 4 mm. wide, obtuse, white; corona filaments in a single series, narrowly linear, 6 to 7 mm. long, white, banded with red or purple; operculum plicate, about 1.5 mm. high, the margin incurved, minutely denticulate; limen annular; ovary ovoid, tapering at apex, stipitate at base, glabrous; fruit narrowly ovoid-clavate, about 6 cm. long (including stipe 1.5 cm. long), 1.5 cm. in diameter; seeds broadly obovate, 3 to 4 mm. long, reticulate, flattened.

[1] Published by permission of the Secretary of the Smithsonian Institution. Received July 8, 1930.

Type in U. S. National Herbarium, no. 1,315,639, collected at Chicavac, Department Tecpán, Guatemala, altitude 2500 meters, December 25, 1926, by G. Salas (no. 584).

Although obviously related to *P. sicyoides* this species bears conspicuous bracts, shaped much like the stipules, and cleft somewhat as in *P. adenopoda*. The leaves are distinctly hastate, proportionately much narrower than in the case of other species of this relationship. The fruit is unusually long and narrow for the group.

The common name is given as "granadilla."

Passiflora tenella Killip, sp. nov.

Slender herbaceous vine, essentially glabrous throughout; stem subangular, striate; stipules setaceous, 1.5 mm. long; petioles very slender, 1 to 2.5 cm. long, glandless, sparingly pilosulous toward apex; leaves transversely oblong in general outline, 1.5 to 3 cm. long, 4 to 7 cm. wide, shallowly 3-lobed at the truncate apex (lobes obtuse or truncate; rarely the leaves distinctly 3-lobed about a third their length), retuse at base, 3-nerved, not ocellate beneath, bright green above, glaucous beneath, thin-membranous; peduncles solitary, 1-flowered, very slender, 2 to 3 cm. long, articulate just below apex; bracts setaceous, 2 mm. long, soon deciduous; flowers about 1.5 cm. wide, greenish white; sepals narrowly lanceolate, 8 to 9 mm. long, 1.5 to 2 mm. wide at base, acutish, 3-nerved, reticulate-veined, thin-transparent; petals linear, 2 to 3 mm. long, obtuse, thin-transparent; corona filaments filiform, in two series, the outer filaments equaling the sepals, the inner barely 2 mm. long; operculum membranous, about 1 mm. high, very slightly plicate; ovary narrowly ellipsoidal, glabrous; fruit ellipsoidal, about 3 cm. long, 0.8 cm. in diameter, tapering to a stipitate base, acuminate at apex, 6-ribbed; seeds narrowly obovate, about 2.5 mm. long, 1.5 mm. wide, transversely 4- or 5-sulcate, the ridges rugulose.

Type in the herbarium of the Field Museum of Natural History, no. 571,848, collected on plain southeast of Hacienda La Choza, Department Tumbez, Peru, altitude 100 to 200 meters, February 28 to March 3, 1927, by A. Weberbauer (no. 7704). Duplicate in U. S. National Herbarium (no. 1,420,160). Additional specimens examined:

PERU: Lima Botanic Garden, said to have come from forests of eastern Peru, *Pennell* 14801 (Herb. Philadelphia Acad. Nat. Sci.).

This interesting species probably belongs to the subgenus *Plectostemma*, although the small operculum, scarcely plicate, and the angular, capsule-like fruit suggest rather a relationship with *P. tryphostemmatoides* and *P. gracillima*, of Harms' group *Tryphostemmatoides*. The flowers, as well as the fruits, resemble those of *P. gracilis*, a wholly different species without petals and with reticulate seeds and glandular petioles. The leaves are shaped much like those of *P. punctata*, another Peruvian species, but the far more delicate flowers, with filiform corona filaments and a glabrous ovary, clearly separate it.

Passiflora dawei Killip, sp. nov.

Stem triangular, striate, minutely puberulous, at length glabrate; stipules narrowly linear-falcate, 9 to 10 mm. long, 1 mm. wide; petioles 3.5 to 4 cm.

long, glandless; leaves broadly ovate-oblong in general outline, 8 to 10 cm. along midnerve, 10 to 14 cm. along lateral nerves, 8 to 10 cm. wide at middle, 6 to 7 cm. wide between the tips of the lobes, 2-lobed about a third their length (lobes lanceolate, acute, the sinus deeply sinuate, mucronulate at base), rounded or subtruncate at base, 3-nerved, ocellate beneath, subcoriaceous, essentially glabrous, bright green (when dry) on both surfaces; peduncles 5 to 7 cm. long, articulate about 1 cm. below apex; bracts narrowly linear, 5 to 6 mm. long, 0.5 to 1 mm. wide; flowers (not fully developed) 3.5 to 4 cm. wide; sepals oblong-lanceolate, 1.5 to 2 cm. long, about 0.8 cm. wide, obtuse; petals similar to and slightly shorter than the sepals; corona filaments in two series, the outer trigonous, conspicuously dilated at and above middle, dark purple, the inner filiform, half as long, minutely capitellate; operculum closely plicate; limen annular; ovary globose, densely white pilose.

Type in the U. S. National Herbarium, no. 1,422,886, collected in the Department of Cundinamarca, Colombia, in February, 1916, by M. T. Dawe (no. 57).

This species is distinguished from *P. chelidonea* by proportionately broader leaves, longer peduncles, larger bracts, and by the shape of the outer corona filaments. It might be confused with *P. alnifolia*, a species common in the Central Cordillera of Colombia, but that has quite differently shaped outer corona filaments, shorter peduncles, and smaller leaves.

Passiflora bucaramangensis Killip, sp. nov.

Slender herbaceous vine, essentially glabrous throughout; stems slightly trigonous, striate, minutely scabrid; stipules narrowly linear-falcate or almost setaceous, 1 to 2 mm. long, reddish purple; petioles slender, 1 to 2.5 cm. long, glandless; leaves transversely oblong, 1 to 3 cm. long, 3 to 7 cm. wide, 3-lobed about a third their length (lobes subequal or the middle lobes slightly the longest, 1 to 2 cm. wide, obtuse or truncate, sometimes emarginate at apex), truncate or cordate at base, 3-nerved (nerves and veins usually prominent beneath), ocellate beneath, subcoriaceous, drying green; peduncles in pairs, about 1.5 cm. long, very slender; bracts setaceous, about 1 mm. long, scattered, persistent; flowers about 2 cm. wide; sepals linear-oblong, about 10 mm. long, 3 mm. wide, obtuse, grass-green, pale at margin; petals oblong, 5 to 6 mm. long, 3 mm. wide, obtuse, white; corona filaments in two series, the outer filaments narrowly linear-clavate, 4 to 5 mm. long, deep purple below, green at the slightly enlarged tip, the inner filaments filiform, 2 to 3 mm. long, grass-green; operculum closely plicate, denticulate at margin, deep purple; limen annular, green; ovary globose; fruit globose, 8 to 9 mm. in diameter; seeds obcordate, 3 mm. long, 2.5 mm. wide, transversely 5-sulcate, the ridges rugulose.

Type in the U. S. National Herbarium, no. 1,352,481, collected near La Baja, north of Bucaramanga, Department Santander, Colombia, altitude 2,400 meters, January 8, 1927, by E. P. Killip and Albert C. Smith (no. 16787).

Additional specimens examined:

COLOMBIA: Santander: Mesa de los Santos, 1,500 meters, *Killip & Smith* 15364 (N). California, 2,200 meters, *Killip & Smith* 17046 (G, N, Y), 18842 (G, N, Y). Tona, 2,000 meters, *Killip & Smith* 19508 (G, N).

This is distinguished from *P. erythrophylla* by equally 3-lobed leaves, the more slender and longer inner filaments of the corona, and by the relative length of the sepals to the petals.

Passiflora popayanensis Killip, sp. nov.

Stem angular, compressed, tortuous, glabrous; stipules linear-setaceous, about 2 mm. long; petioles up to 1.5 cm. long, minutely pilosulous, glandless; leaves oblong or ovate-oblong, 5 to 7 cm. long, 3 to 3.5 cm. wide, bilobed (lobes lanceolate, 2 to 2.5 cm. long, acuminate, mucronulate, the sinus truncate, often with a small intermediate lobe present), rounded at base, 3-nerved, membranous, glabrous, dark green, usually paler along nerves above, glaucous beneath; peduncles slender, up to 3 cm. long, articulate just below apex; bracts setaceous, 2 to 4 mm. long, borne above middle of peduncle; flowers 3 to 3.5 cm. wide; sepals oblong-lanceolate, 1.2 to 1.5 cm. long, about 0.4 cm. wide, obtuse; petals spatulate, 6 to 7 mm. long, about 3 mm. wide, obtuse, reticulate-veined toward apex, white, the veins darker; corona filaments in two series, filiform, the outer 6 to 7 mm. long, the inner 4 to 5 mm. long; operculum slightly plicate, the margin minutely fimbrillate; nectar ring annular; limen cushion-like, closely surrounding the base of gynophore; gynophore very slender; ovary ovoid, glabrous.

Type in the U. S. National Herbarium, collected on Sotará Volcano, near Popayán, Department El Cauca, Colombia, altitude 2,400 to 2,900 meters, March 3, 1884, by F. C. Lehmann (no. 3731).

This specimen is cited by Masters as *P. chelidonea* Mast. in a report of Lehmann's Passifloraceae,[2] and is the original of a detailed drawing of "*P. chelidonea.*"[3] The thinner, more deeply lobed leaves, glaucous beneath, the longer peduncles, more slender corona filaments, the two series of which are of nearly equal length, and the smaller flowers distinguish *P. popayanensis* from *P. chelidonea*. The ovary is glabrous, that of *P. chelidonea* densely puberulent.

Passiflora lyra Planch. & Linden, sp. nov.

Stem sharply angular, puberulent; stipules setaceous, 5 to 10 mm. long, deciduous; petioles stout, up to 2.5 cm. long, glandless; leaves ovate-lanceolate, 8 to 12 cm. long, 5 to 8 cm. wide, narrowed near the truncate apex, shallowly 2 (or obscurely 3)-lobed (lobes less than 1 cm. long, acute), rounded at base, subcoriaceous, shining and very dark green and finely and sparsely puberulent above, reddish and densely and softly tomentulous beneath, bearing two conspicuous, white, sub-crustaceous glands in the angles of the nerves; flowers white, about 4 cm. wide, on axillary branches up to 10 cm. long which bear much reduced leaves; bracts setaceous, about 5 mm. long; sepals lanceolate, about 1.5 cm. long, 0.5 cm. wide, acutish; petals linear, about 5 mm. long, 2 mm. wide, very slender; corona filaments in two series, the outer filiform, 4 to 5 mm. long, slightly torulose, the inner capillary, 2 mm. long, capitellate; operculum membranous, slightly plicate, erect, irregularly lacerate to middle, about 2 mm. high; limen annular; ovary ovoid, densely brown-pilose.

[2] Bot. Jahrb. Engler 8: 218. 1887.

[3] HARMS in Engl. & Prantl Nat. Pflanzenfam. Aufl. 2, 21: 499, *f.* 330, *C, D.* 1925.

Type in the herbarium of the Muséum d'Histoire Naturelle, Paris, collected at Cumbre de Valencia, State of Carabobo, Venezuela, May, 1846, by Funck and Schlim (no. 552).

The leaves of this species are much like those of typical forms of *P. chelidonea* in general outline, though much less deeply lobed. The dense indument on the ovary and under surface of the leaves and the position of the flowers on short axillary branches are the most obvious characters by which *P. lyra* may be distinguished from *P. chelidonea*.

Passiflora smithii Killip, sp. nov.

Plant glabrous throughout; stem terete; stipules semi-ovate or subreniform, 2.5 to 3.5 cm. long, 1 to 1.5 cm. wide, aristulate at apex, rounded at base, coriaceous; petioles 2.5 to 4 cm. long, 2- to 4-glandular near middle, the glands 0.5 mm. long; leaves 8 to 12 cm. long, 10 to 15 cm. wide, 3-lobed about three-quarters their length (lobes oblong or elliptic-oblong, 2.5 to 3 cm. wide, narrowed to an obtuse apex, minutely glandular-serrulate in the rounded sinuses), subtruncate or cordulate at base, 5-nerved, strongly reticulate-veined, coriaceous or subcoriaceous; peduncles 6 to 7 cm. long, slender; bracts narrowly lanceolate, 6 to 8 mm. long, 2 to 3 mm. wide, acuminate, sessile, deciduous, borne at separate points near middle of peduncle; flowers about 5 cm. wide; calyx tube broadly campanulate, about 5 mm. long, 10 mm. wide; sepals oblong, about 2 cm. long, 0.7 cm. wide, obtuse, slightly cucullate, minutely awned dorsally (awn about 1 mm. long); petals linear-oblong, about 1 cm. long, 0.4 cm. wide, obtuse; corona filaments in several series, the outermost narrowly liguliform, 0.8 to 1 cm. long, the succeeding 3 or 4 series filiform, about 2 mm. long, minutely capitellate; operculum membranous, about 7 mm. high, closely plicate, lacerate-cleft to below middle; nectar ring annular, obscure; limen about 4 mm. high, closely surrounding base of gynophore, irregularly denticulate; ovary ovoid, glabrous; fruit ovoid, about 6 cm. long, 3 to 3.5 cm. in diameter; seeds oblong, about 6 mm. long, reticulate.

Type in the U. S. National Herbarium, no. 1,350,965, collected on northern slope of Mesa de los Santos, Department Santander, Colombia, altitude 1200 meters, December 11, 1926, by E. P. Killip and Albert C. Smith (no. 15015).

Additional specimen examined: COLOMBIA: Department Cundinamarca, Tequendama Falls, 1,000 meters, *Triana* 2947, in part (British Museum).

The tendency among students of *Passiflora* has been to place in the subgenus *Granadilla* all species with large involucral bracts and a complicated coronal structure, subdividing *Granadilla* on the basis of the leaf shape, stipules, and other vegetative characters, thus failing to bring together species that evidently are closely related in flower structure. Harms has suggested[4] a more logical treatment in his recent revision of the family, although he here considers only a part of the described species. *Passiflora kermesina* Link & Otto (*P. raddiana* DC.) he places by itself in a separate series (no. 2) of *Granadilla*, characterized by small bracts and a plicate filamentose operculum.

[4] Engl. & Prantl Nat. Pflanzenfam. Aufl. 2, 21: 502-504. 1925.

To this series should be referred *P. miersii*, *P. lehmannii*, *P. trisulca*, *P. watsoniana*, *P. eggersii*, and *P. smithii*. From *P. trisulca*, with which it appears to be most closely related, the proposed species differs in less deeply lobed leaves which have obtuse apices, and in the shape of the petiolar glands.

Apparently two species are represented by Triana's 2947. The plant at Geneva is *P. subpeltata* Ort. (*P. alba* Link & Otto), but the plant at the British Museum is distinct. Triana and Planchon cited no. 2947 as *P. stipulata* (*P. subpeltata*, not. *P. stipulata* Aubl.). Triana's 2946, seen at Paris and in the British Museum is also *P. subpeltata*.

Passiflora cuzcoensis Killip, sp. nov.

Plant glabrous throughout; stem terete, or the younger portions subangulate; stipules semi-oblong, 2 to 2.5 cm. long, 0.7 to 0.9 cm. wide, acutish at apex, rounded at base, obscurely crenulate; petioles 2 to 3 cm. long, slender, biglandular in upper third, the glands minute, subulate, 0.5 to 0.8 mm. long; leaves suborbicular in general outline, 3-lobed at apex, 5 to 7 cm. along midnerve, 4 to 6 cm. along lateral nerves (lobes rounded, minutely mucronulate the middle lobe 2 to 3 cm. wide), rounded or subtruncate at base, entire, 5 (or obscurely 7)-nerved, membranous; peduncles slender, 3 to 3.5 cm. long; bracts 3, subimbricate, unequal (one larger than the others), cordate, 2.5 to 3 cm. long, 2 to 2.5 cm. wide, obtuse, crenate-serrulate toward apex, persistent; flowers about 5 cm. wide; calyx tube campanulate; sepals lance-oblong, about 2 cm. long, 1 cm. wide, obtuse, awned dorsally just below apex, the awn foliaceous, up to 5 mm. long; petals lance-oblong, about 1.5 cm. long, 0.8 cm. wide, obtuse; corona filaments in two series, the outer radiate, about 2 cm. long, very slender, apparently concolorous, the inner (borne about 2 mm. from the outer), filiform, 1.5 to 2 mm. long; operculum membranous, about 2 mm. high, denticulate, bearing on outside just below margin a row of very slender filaments about 1 mm. long; limen cupuliform, closely surrounding base of gynophore; ovary not seen.

Type in the U. S. National Herbarium, no. 1,442,740, collected in Marcapata Valley, near Chilechile, Province Guispicanchi, Department Cuzco, Peru, February 21, 1929, by A. Weberbauer (no. 7872).

The unusual arrangement of the bracts indicates the relationship of this species to *P. tetraden*, which it resembles also in the outline of the leaves. The flowers of the two species differ in several details: In *P. cuzcoensis* the sepals are awned, in *P. tetraden* they are without awns, apparently an important difference in the subgenus *Granadilla* to which both belong; the principal or radiate corona filaments are in a single series and concolorous in *P. cuzcoensis*, in two series and alternately banded with blue and white in *P. tetraden*; the inner corona consists of short filaments in *P. cuzcoensis*, of mere tubercles in *P. tetraden*.

Passiflora spectabilis Killip, sp. nov.

Herbaceous vine, glabrous throughout; stem terete, the younger portions subangular; stipules semi-ovate or semi-oblong, 2 to 6 cm. long, 0.8 to 4 cm. wide, obtuse and mucronulate at apex (mucrone up to 1.5 mm. long), rounded at base, entire or undulate, the midnerve eccentric; petioles 3 to 8 cm. long,

bearing two subopposite (or three scattered) sessile ovate glands about 1. 5 mm. long, leaves 3-lobed not more than to middle, 6 to 12 cm. along midnerve, 5 to 10 cm. along lateral nerves, 10 to 20 cm. wide (lobes broadly triangular, obtuse or subacute), peltate 5 mm. or more from lower margin (at least the older leaves), 5-nerved, subcoriaceous, glaucescent beneath, at length green; peduncles solitary, 3 to 6 cm. long, articulate at least 5 mm. from apex; bracts ovate, 6 to 7 mm. long, 2 to 3 mm. wide, acute at apex, narrowed at the sessile base, green, borne at point of articulation; flowers 5 to 7 cm. wide; sepals oblong, about 4 cm. long, 1 cm. wide, obtuse, slightly carinate, short-awned (awn 0.5 to 1 mm. long), fleshy, green without, light pink or white within; petals linear, about 2.5 cm. long, 0.4 cm. wide, obtuse, light pink or white; corona filaments filiform, very slender, in four series, those of the two outer about 2.5 cm. long, blue, white at tips, those of the inner 2 to 2.5 mm. long, bifid at apex, white; operculum about 7 mm. high, filamentose nearly to base, the filaments white, blue in upper third; limen tubular, about 5 mm. high, closely surrounding base of gynophore; ovary subglobose; fruit globose, 5 cm. in diameter, purplish when ripe, edible; seeds obovate, about 8 mm. long, 5 mm. wide, coarsely reticulate.

Type in the U. S. National Herbarium, no. 1,356,557, collected at Mishuyacu, about 15 kilometers southwest of Iquitos, Department Loreto, Peru, altitude 100 meters, September 26, 1929, by E. P. Killip and A. C. Smith (no. 29884). Duplicates in the New York Botanical Garden and the Field Museum of Natural History.

Additional specimens examined:

PERU: Junín: Pichis Trail, Eneñas, 1600 meters, *Killip & Smith* 25764. Loreto: Iquitos, 100 meters, *Killip & Smith* 27165.

This is related to the Bolivian plant *P. rubrotincta*, both of these species being peltate much farther from the margin than in the case of other representatives of the subgenus *Granadilla*. *Passiflora spectabilis* has proportionately broader leaves than *P. rubrotincta*, smaller bracts which are borne fully 5 mm. below the flower, and very short awns to the sepals.

Locally this is known as *pucu-pucu*.

Passiflora crassifolia Killip, sp. nov.

Herbaceous tendril-bearing vine; stem subterete, striate, densely villous with spreading grayish hairs; stipules subreniform, 1.5 to 2.5 cm. long, 0.6 to 1 cm. wide, subamplexicaul, aristate (awn about 4 mm. long), reticulate-veined, coriaceous, glabrous above, villous on veins beneath and at margin; petioles villosulous, 2 to 6 cm. long, bearing 4 to 6 subsessile glands, dissitate the whole length of the petiole, 0.6 to 0.8 mm. in diameter; leaves lanceolate or ovate-lanceolate, 10 to 18 cm. long, 6 to 12 cm. wide, not lobed or occasionally obsoletely lobed in lower third, obtuse at apex, deeply cordate at base with a narrow sinus, entire or sparingly serrulate toward base, 7-nerved, reticulate-veined (nerves and veins prominent beneath), entire, thick-coriaceous, dark green and glabrous above, paler and appressed-villous on the nerves and veins beneath; peduncles solitary, about 5 cm. long, villous; bracts lanceolate, 1.5 to 2 cm. long, 0.7 to 0.8 cm. wide, sharp-acuminate at apex, cordulate, subsessile, glabrous above, villous on nerves and veins beneath, borne about 5 mm. below base of flower; calyx tube tubular-campanulate, about 5 mm. long, 6 mm. in diameter; sepals oblong, dorsally awned, the awn 2 to 3 mm.

long; corona filaments in three or four series, the outermost about 7 mm. long; operculum membranous, about 5 mm. high, filamentose in upper half; fruit ovoid or ellipsoidal, 4 to 6 cm. long, 2 to 2.5 cm. wide, villosulous; seeds narrowly oblong, 6 to 7 mm. long, 2 to 3 mm. wide, shallowly tridentate at apex, coarsely reticulate.

Type in the U. S. National Herbarium, no. 1,356,480, collected in thickets, La Merced, Department Junín, Peru, altitude 700 meters, May 29, 1929, by E. P. Killip and A. C. Smith (no. 23434).

Additional specimens examined:

PERU: Junín: La Merced, *Killip & Smith* 23382; *Macbride* 5371. Along Perené River, near "Hacienda 3," Colonia Perené, altitude 600 meters, *Killip & Smith* 25181.

This species is related to *P. menispermifolia* and *P. nephrodes*, differing from both in having essentially entire leaves. In addition, the bracts of *P. menispermifolia* are much narrower and glandular-denticulate, and in *P. nephrodes* the petiolar glands are much more slender. The specimens examined are all in fruit, with badly withered floral parts, so that an accurate description of the coronal structure is not possible. Apparently the outermost corona filaments are much shorter than in *P. menispermifolia* or *P. nephrodes*.

BOTANY.—*Four new grasses.*[1]

A. S. HITCHCOCK, Bureau of Plant Industry.

Recently Professor L. F. Henderson, Curator of the herbarium of the University of Oregon, Eugene, sent to the Grass Herbarium of the U. S. National Herbarium for identification, a specimen of grass which represents an undescribed species. In a region so well explored as western Oregon, it was surprising to find a novelty among the grasses.

The grasses recently collected in Peru by E. P. Killip and A. C. Smith were submitted to me for identification. Among these specimens there were two undescribed species, as well as several species not included in the grass flora of Peru as described in the "Grasses of Ecuador, Peru, and Bolivia" by Hitchcock (Contr. U. S. Nat. Herb. 24: 291–556, 1927).

The fourth species here proposed is based on a specimen collected in Chile, but submitted by Dr. Ivan M. Johnston of the Gray Herbarium.

Agrostis hendersonii Hitchc., sp. nov.

Plant apparently annual; culms slender, erect, 2-noded, glabrous, about 11 cm. tall; sheaths glabrous; ligule membranaceous, acute, 2 to 3 mm. long; blades flat or loosely involute, glabrous, 1 to 3 cm. long, 1 mm. wide; panicle condensed, about 2.5 cm. long, purplish tinged; spikelets short-pediceled, 5 to

[1] Received July 9, 1930.

bearing two subopposite (or three scattered) sessile ovate glands about 1. 5 mm. long, leaves 3-lobed not more than to middle, 6 to 12 cm. along midnerve, 5 to 10 cm. along lateral nerves, 10 to 20 cm. wide (lobes broadly triangular, obtuse or subacute), peltate 5 mm. or more from lower margin (at least the older leaves), 5-nerved, subcoriaceous, glaucescent beneath, at length green; peduncles solitary, 3 to 6 cm. long, articulate at least 5 mm. from apex; bracts ovate, 6 to 7 mm. long, 2 to 3 mm. wide, acute at apex, narrowed at the sessile base, green, borne at point of articulation; flowers 5 to 7 cm. wide; sepals oblong, about 4 cm. long, 1 cm. wide, obtuse, slightly carinate, short-awned (awn 0.5 to 1 mm. long), fleshy, green without, light pink or white within; petals linear, about 2.5 cm. long, 0.4 cm. wide, obtuse, light pink or white; corona filaments filiform, very slender, in four series, those of the two outer about 2.5 cm. long, blue, white at tips, those of the inner 2 to 2.5 mm. long, bifid at apex, white; operculum about 7 mm. high, filamentose nearly to base, the filaments white, blue in upper third; limen tubular, about 5 mm. high, closely surrounding base of gynophore; ovary subglobose; fruit globose, 5 cm. in diameter, purplish when ripe, edible; seeds obovate, about 8 mm. long, 5 mm. wide, coarsely reticulate.

Type in the U. S. National Herbarium, no. 1,356,557, collected at Mishuyacu, about 15 kilometers southwest of Iquitos, Department Loreto, Peru, altitude 100 meters, September 26, 1929, by E. P. Killip and A. C. Smith (no. 29884). Duplicates in the New York Botanical Garden and the Field Museum of Natural History.

Additional specimens examined:

PERU: Junín: Pichis Trail, Eneñas, 1600 meters, *Killip & Smith* 25764. Loreto: Iquitos, 100 meters, *Killip & Smith* 27165.

This is related to the Bolivian plant *P. rubrotincta*, both of these species being peltate much farther from the margin than in the case of other representatives of the subgenus *Granadilla*. *Passiflora spectabilis* has proportionately broader leaves than *P. rubrotincta*, smaller bracts which are borne fully 5 mm. below the flower, and very short awns to the sepals.

Locally this is known as *pucu-pucu*.

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Herbaceous tendril-bearing vine; stem subterete, striate, densely villous with spreading grayish hairs; stipules subreniform, 1.5 to 2.5 cm. long, 0.6 to 1 cm. wide, subamplexicaul, aristate (awn about 4 mm. long), reticulate-veined, coriaceous, glabrous above, villous on veins beneath and at margin; petioles villosulous, 2 to 6 cm. long, bearing 4 to 6 subsessile glands, dissitate the whole length of the petiole, 0.6 to 0.8 mm. in diameter; leaves lanceolate or ovate-lanceolate, 10 to 18 cm. long, 6 to 12 cm. wide, not lobed or occasionally obsoletely lobed in lower third, obtuse at apex, deeply cordate at base with a narrow sinus, entire or sparingly serrulate toward base, 7-nerved, reticulate-veined (nerves and veins prominent beneath), entire, thick-coriaceous, dark green and glabrous above, paler and appressed-villous on the nerves and veins beneath; peduncles solitary, about 5 cm. long, villous; bracts lanceolate, 1.5 to 2 cm. long, 0.7 to 0.8 cm. wide, sharp-acuminate at apex, cordulate, subsessile, glabrous above, villous on nerves and veins beneath, borne about 5 mm. below base of flower; calyx tube tubular-campanulate, about 5 mm. long, 6 mm. in diameter; sepals oblong, dorsally awned, the awn 2 to 3 mm.

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6 mm. long; glumes subequal, with a setaceous slightly spreading tip 1 to 2 mm. long; lemma about 3 mm. long, with 2 setaceous teeth about 0.5 mm. long at the summit, the base or callus pubescent; awn from the middle of the back of the lemma, about 1 cm. long, twice-geniculate, the first bend often somewhat obscure; palea obsolete.

Planta annua (?); culmi erecti, 10 cm. alti, ligula 2–3 mm. longa; panicula condensa, 2.5 cm. longa, purpurascens; glumae subaequales, 5–6 mm. longae, aristatae; lemma 3 mm. longum, 2-aristatum, aristis 0.5 mm. longis, e dorso medio aristam emittens, arista 2-geniculata, 1 cm. longa, callo pubescente; palea nulla.

Type in the U. S. National Herbarium, no. 1,445,585, collected on wet ground, Sams Valley, a few miles from Gold Hill, Jackson County, Oregon, May 4, 1930, by L. F. Henderson (no. 12387).

The specimen at hand has the aspect of a depauperate plant of *Agrostis microphylla* Steud., but differs in the longer awn and in the two setaceous teeth of the lemma. Only two plants were found by Professor Henderson and these may be depauperate specimens. The duplicate type is in the herbarium of the University of Oregon, Eugene.

Calamagrostis stipitata Hitchc., sp. nov.

Plant perennial, stramineous, rather soft; culms densely cespitose, erect, glabrous, 5 to 10 cm. tall; sheaths glabrous, scarious-margined, the uppermost inflated, 3 to 5 mm. wide as folded; ligule membranaceous, acute, 5 to 8 mm. long; blades erect, glabrous, involute, filiform, not more than 0.5 mm. thick, pungently pointed, mostly exceeding the culms; panicles condensed, 1 to 3 cm. long, tinged with purple or bronze, mostly partly included in the sheath, the axis and branchlets minutely hispid; spikelets 3.5 mm. long; glumes equal, acute, glabrous, scabrous on the keel, the tip somewhat erose; floret stipitate, the rachilla internode about 0.5 mm. long; lemma 2 mm. long, the callus hairs copious, as long as the lemma, the apex with 4 rather stout teeth, the awn borne below the middle, straight or a little bent, slightly exceeding the glumes; palea a little shorter than the lemma; prolongation of the rachilla about 0.5 mm. long, the rachilla hairs copious like the callus hairs.

Planta perennis, straminea; culmi dense caespitosi, erecti, 5–10 cm. alti; ligula membranacea, acuta, 5–8 mm. longa; laminae erectae, graciles, involutae, glabrae, quam culmi paullo longiores; panicula condensa, 1–3 cm. longa; spiculae 3.5 mm. longae; glumae acutae; floscula stipitata; lemma 2 mm. longum, aristatum, arista recta glumas paullum superante, apice 4-dentata, callo dense piloso, pilis 2 mm. longis; palea quam lemma paullo brevior; processus rhachillae 0.5 mm. longus, pilis 2 mm. longis.

Type in the U. S. National Herbarium, no. 1,445,584, collected in gravel along a streamlet, Mina Desputada (Los Condes), Prov. Santiago, Chile, alt. 4000 to 4100 meters, January, 1930, by G. Looser (no. 1114).

Also collected in the Cordilleras of Colchaqua, Chile, January, 1930, by Padre Anastasio Pirion (no. 117).

Stipa smithii Hitchc., sp. nov.

Plant perennial; culms closely cespitose, erect, glabrous, usually 3-noded, about 60 cm. tall; sheaths glabrous; ligule a truncate membrane about 0.5

mm. long: blades erect, rather loosely involute, glabrous on the outer surface, rather rigid, acuminate to a fine hard point, 10 to 15 cm. long; panicle erect, narrow but scarcely spikelike, interrupted below, 10 to 18 cm. long, the branches appressed, the lower as much as 4 cm. long, the main axis glabrous, the branches and pedicels pubescent; spikelets strongly tinged with purple; glumes equal, about 6 mm. long, 3-nerved, lanceolate, acuminate, sometimes sparingly pubescent near base; lemma 3 mm. long, including the acute callus about 0.5 mm. long, oblong, brownish, loosely pilose with white appressed hairs, the summit whitish, the margins of the lemma extended into minute lobes, the overlapping one indurate and forming a minute blunt tooth at the summit of the lemma; awn early-deciduous, twice-geniculate, sometimes obscurely so, scabrous, about 14 mm. long, the first segment twisted, about 5 mm. long, the second segment like the first, 2 mm. long, the third segment straight, about 7 mm. long.

Planta perennis; culmi caespitosi, erecti; laminae laxe involutae, glabrae, erectae, rigidae, 10–15 cm. longae; panicula erecta, angusta, 10–18 cm. longa, ramis appressis; spiculae purpurascentes; glumae acuminatae, 6 mm. longae, 3-nervae, basi paullum pubescentes; lemma oblongum, pubescens, 3 mm. longum, apice minute dentato; arista 2-geniculata, scabra, inferne torta, circ. 14 mm. longa.

Type in U. S. National Herbarium, no. 1,357,804, collected on open hillside, Río Blanco, Dept. Lima, Peru, alt. 3000 to 3500 meters, April, 1929, by E. P. Killip and A. C. Smith (no. 30669).

Panicum killipii Hitchc., sp. nov.

Plant perennial: culms erect, sparingly branching, glabrous, solitary or few in a tuft, 100 to 150 cm. tall; sheaths glabrous, sometimes tuberculate-hispid on the margins; ligule a membrane about 1 mm. long, the upper surface of the blade just above densely hispid; blades flat, narrowly lanceolate, acuminate, the upper rounded or somewhat cordate, the lower narrowed into a petiole-like folded base, glabrous beneath, the upper surface often sparsely beset along the nerves with tuberculate hairs or with tubercles only, minutely roughened along the margin especially toward the apex, 20 to 35 cm. long, 2 to 3 cm. wide, the uppermost smaller; panicle erect, ovate-pyramidal in outline, 15 to 25 cm. long, the axis glabrous on the lower part, scabrous above, the branches ascending or the lower spreading, solitary or 2 or 3 together, the lower as much as 12 cm. long, 1 to 3 cm. distant, the upper successively shorter and more crowded, sometimes a few long hairs in the axils, the spikelets short-pediceled, rather crowded and more or less secund on the primary branches, the lower branches sometimes again branching; spikelets purplish, glabrous, oval-oblong, obtuse, about 2 mm. long, single or in pairs on flat slightly scabrous pedicels, mostly shorter than the spikelets; first glume narrow, acute or acuminate, nerveless, from minute to nearly half as long as the spikelet; second glume and sterile lemma subequal, 5-nerved, the glume sometimes with a few delicate hairs at the summit; sterile floret staminate, with large anthers, the hyaline palea as long as the lemma; fruit as long as the spikelet, plano-convex, slightly apiculate, pale, smooth and shining.

Planta perennis; culmi erecti, glabri, 100–150 cm. alti; laminae planae, anguste lanceolatae, 20–35 cm. longae, 2–3 cm. latae, acuminatae, superiores cordatae vel rotundatae, inferiores basi longe attenuatae, panicula pyramidalis,

15–25 cm. longa, ramis ascendentibus, inferioribus 7–12 cm. longis; spiculae glabrae, ovato-oblongae, obtusae, 2 mm. longae, subsecundae, breviter pedicellatae; gluma prima, acuta, 0.5–1 mm. longa; gluma secunda et lemma sterile subaequales, 5-nervia; flos sterilis masculus, palea magna; lemma fertile paullum apiculatum.

Type in the U. S. National Herbarium, no. 1,357,803, collected in thickets, Aina, between Huanta and Río Apurimac, Dept. Ayacucho, Peru, alt. 750 to 1000 meters, May, 1929, by E. P. Killip and A. C. Smith (no. 22804). Also in the same locality, Killip & Smith 22522, 22803; Ccarrapa, same region, Killip & Smith 22491.

This plant is not closely allied to any known species.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

ENTOMOLOGICAL SOCIETY

418TH MEETING

The 418th regular meeting of the Entomological Society of Washington was held at 8 p.m. Thursday, March 6, 1930, in Room 43 of the new building of the U. S. National Museum. President J. E. GRAF presided; there were present 37 members and 24 visitors. C. GRAHAM and F. F. MURDOCK were elected to membership.

The first communication on the regular program was presented by Mr. O. E. GAHM, of the Bureau of Entomology, and was entitled "*Insect Pests and Mites Related to the Mushroom Industry.*"

History, Development and Present Status of the Industry in the U. S.

"The mushroom industry is comparatively young and is perhaps one of the most centralized of its kind in this country, as nearly 80% of all the mushrooms grown in the U. S. are raised in the southern halves of Chester and Delaware Counties, Pa., representing a radius of not more than 25 miles. The remaining 20% of our commercial production is scattered throughout several states, the principal ones being New York, Ohio, Michigan, Illinois, Missouri, Minnesota, Colorado, Washington, Oregon, and California.

The growth of the industry is rather unique in that commercial production began as a sideline with two greenhouse men at Kennett Square about 40 years ago. Since that time the industry has developed into a business representing a capital investment of over $10,000,000 for growing houses and equipment, the annual production of mushrooms in Pennsylvania being about 15,000,000 pounds and having a total value of over $5,000,000.

The Industry in New York State—Adaptation of Ice Houses

While the bulk of the crop is grown in specially constructed houses, there have been a few adaptations whereby certain buildings and caves are now being used for the culture of mushrooms. One of the most noted of these adaptations is found in New York State where the largest mushroom plant in the world exists today. This plant consists of several abandoned ice houses along the Hudson River, from Kingston to Albany, which have been converted into mushroom houses and comprise a total of about 1,500,000 sq. ft. of bed

space for the growing of mushrooms. In reconditioning these houses, the floors were cemented and a false ceiling 8 feet from the floor was made by fastening a network of twine string to strong twine supports or ropes suspended from the rafters, and then covering the twine network with 3 to 5 ply of building paper. From 4 to 5 carloads of building paper are used each season in making these false ceilings. Knock-down type construction beds were made of California spruce, which are 4 tiers high. Large removable doorways were made in the side of the houses which permit the trucks to haul the manure directly into and out of the houses. This company has a standing order with the manure dealers in New York City for over 10,000 tons of horse manure each year. All this manure is brought up the Hudson River on barges and unloaded with cranes into motor trucks which haul it directly into the ice houses where it is composted. Most of the labor involved in composting and turning of the manure is done by special machinery. The spent compost is loaded into trucks, dumped on barges and shipped South.

Six of these large ice houses are equipped for use in the summer. Large, well insulated rooms were constructed in the center of the ice house proper, in which 6,000 to 10,000 tons of ice are stored in the winter and used in summer for cooling. When the temperature rises above the optimum for mushroom culture, slide doors in the ice chamber are opened and the cool air is forced out into the plant by means of electric fans.

The growers in the ice houses estimated their production for the summer of 1929 to be around 145,000 three-pound baskets of mushrooms.

There are also some large limestone caves in New York State where mushrooms are grown the year round, but climatic conditions are not as favorable for successful culture of mushrooms in the caves as in the reconditioned ice houses.

Industry in the Northwest

The industry in the Northwest is centered around the twin cities, Minneapolis and St. Paul, where between 300,000 and 400,000 pounds of mushrooms are grown annually in the sandstone caves or mines along the banks of the Mississippi River, which have been mined out for the extremely high grade sand used for manufacture of glass. Some of these mines are enormous in size, being from 300 to 400 feet long, 30 feet high and 30 feet wide. The temperature remains fairly constant the year round and affords a favorable place for the culture of mushrooms. There are, however, some hazardous factors which enter into the culture in these sandstone caves, which will be mentioned later.

The industry has gradually spread westward and at the present time there are large mushroom plants at San Francisco, Whittier and Redwood City, California, and at Denver, Colorado. Plants are in the process of construction at Seattle, Washington, and at Portland, Oregon. The annual production of mushrooms on the West Coast is approximately 1,000,000 pounds.

Insect Pests and Mites Associated with Mushroom Culture

It seems as though the insect pests and mites have kept pace with the growth of the industry, and as the industry became more centralized, the flies flew from one house to another and in many instances carried the mite hypopi with them. The chief insect pests found in the commercial mushroom houses are the Sciarid, Phorid and Cecid flies, springtails and sowbugs. The injurious mites include the so-called mushroom mite *Tyroglyphus lintneri*,

Rhizoglyphus phylloxerae and *Linopodes antennaepes*. The Sciarid larvae do considerable injury by destroying the mycelium in the beds and also by feeding on the small mushrooms which they completely devour in many instances. They are also productive of commercial damage to the larger sporophores which are rendered unfit for the market when the larvae tunnel up into the stem and cap. The Phorid larvae are often quite numerous in the compost but do not cause the damage which the Sciarid larvae are capable of producing. The writer has not yet found any of the Phorid larvae up in the stem or cap of the mushroom. The larvae of the Cecid fly also produce injury by burrowing into the cap as well as the damage which they cause by destroying the mycelium in the beds. The flies being vectors of disease are also serious pests of the mushroom industry in this connection.

Springtails cause very little damage to mushrooms in the East, but are however one of the most serious pests which the growers in the sandstone caves of the Northwest have to contend with. While the species found in the sandstone caves has never been described in the United States, I doubt very much whether it would cause commercial damage in the modern constructed houses in the East due to unfavorable climatic conditions for their reproduction.

Mites have become one of the major pests of cultivated mushrooms and are capable of producing considerable injury to the crop. The one most commonly found is the so-called mushroom mite *Tyroglyphus lintneri*. *Rhizoglyphus phylloxerae* which resembles *Tyroglyphus lintneri* is also quite prevalent. These mites are very destructive to the mycelium and also render many of the sporophores unfit for market by eating into the stem and cap. Many of the plants in Pennsylvania were infested with this mite this season, and one plant in Ohio comprising 91,000 sq. ft. of bed space was heavily infested and approximately $10,000 worth of damage produced.

Another mite, *Linopodes antennaepes*, a new pest of mushrooms in this country, apparently made its appearance in one of the commercial houses in Pennsylvania last March and was found during the summer of 1929 in mushroom houses at Ashtabula, Ohio, Naperville, Illinois, and in one of the sandstone caves at St. Paul, Minnesota.

The yield was reduced about 40% in the plant at Ashtabula, Ohio, which consisted of 375,000 sq. ft. of bed space. Control of this mite was received by passing steam over the surface of the manure after the last turning and before it was taken into the houses.

Control Measures

There exists in the preparation of the compost for mushroom culture a natural means of insect and mite control, which if properly utilized would aid materially in reducing heavy insect and mite infestations. The compost usually undergoes a secondary fermentation process after it is put into the house during which period the temperature in the compost in the top bed rises to the point where all insect and mite life present in the manure is either killed or driven to the surface of the bed, where fumigants can be used effectively. The temperature of the compost in the bottom beds seldom rises above 110 to 115°F. and does not go this high in most cases if beds are built on the ground. The temperature in the bottom beds being low, the insects are neither killed nor driven to the surface where fumigants can be used effectively, and hence these beds serve as breeding grounds or sources of pollution for the whole house.

Preliminary tests with electric fans to break up the dead air space and circulate the air have every indication of being both practical and profitable for this purpose. Three 16-inch oscillating electric fans placed in a single mushroom house, 50 ft. long, with the face of the fan pointed upward at an angle of 45° will circulate the air very well. By this means we have been able to get the air temperature in the bottom of the houses the same as it was in the top of the houses; and where the bottom beds are raised off the ground to get the temperature of the compost within 2° of the compost temperature in the top beds. In using fans, they should not be started until the temperature of the compost in the top beds has reached 125 to 130°F. The fans not only equalize the temperatures, thereby either killing the insects in the manure or driving them to the surface where fumigants can be used effectively; but also serve as a means whereby the house can be left closed for a longer period of time without danger of burning the manure in the top beds.

Precautionary Measures

Due to the fact that some of the mushroom pests are almost invariably present in the compost when it enters the mushroom house, it is necessary to take certain precautions while the compost is going through its secondary decomposition process to prevent heavy infestations of flies and mites. Calcium cyanide has been recommended and used when the compost was at its peak heat for the control of insect pests and mites in the compost. It is scattered in the aisles at the rate of one pound per 1,000 cu. ft. of air space in the mushroom house. Results of aspiration experiments conducted in the mushroom house under practical conditions show that the gas is liberated very quickly, the maximum concentration being received at the time of the first aspiration, which was made 15 minutes after the calcium cyanide had been scattered in the aisles. Starch papers dipped in picric acid were inserted in the compost to determine the depth to which the hydrocyanic acid gas penetrated. These tests showed that the gas did not penetrate into the compost more than one inch; hence the necessity of driving the insects and mites to the surface. Due to the fact that hydrocyanic acid gas does not seem to be as effective on mite hypopi as sulfur dioxide several experiments were conducted in the mushroom houses in Pennsylvania during the fall of 1929 whereby sulfur was burned in the houses at the rate of 1 to 3 pounds per 1,000 cu. ft. of air space when the compost was at peak heat. pH determinations of the compost were made before and after the sulfur was burned. Results of several determinations showed that the pH of the compost on the surface changed from about 7.5 to about 6.5, or roughly one point, while the pH of the compost from the center of the bed remained unchanged showing that the sulfur fumes did not penetrate far into the compost. A greenish mold developed on the surface of the compost after the house had been cooled down, but apparently dried up before the beds were cased and did no harm. Yield tests from several of the houses in which sulfur was burned showed normal crops. While there is a slight fire hazard in using sulfur for fumigation at this time, it is much cheaper and apparently a better miticide than hydrocyanic acid gas.

Results of preliminary tests with ethylene oxide indicate that it is very effective against mites, but further experiments as to its effect on the mushroom and mycelium will have to be made before it can be tried on a commercial scale in the mushroom houses. It is a very penetrating gas, having killed mites which were buried in compost at a depth of 3 inches when used at the

rate of 1 pound per 1,000 cu. ft. of air space. Due to the extreme sensitivity of the mushroom and of the mycelium, very few fumigants can be used while a crop is on the beds. Pyrethrum powder is the most extensively used insecticide for control of flies during the cropping period. A 100% active pyrethrum dust was used until the fall of 1929. It was too heavy and did not remain in suspension long enough for most effective results. A 60–40 pyrethrum diatomaceous earth combination is now being used in considerable quantity and has proven more effective than the 100% active pyrethrum dust. The new dust not only remains in suspension longer thereby becoming more effective than the heavier dust but is also about 25¢ per pound cheaper than the 100% material. Nicotine smudges as well as a special pyrethrum smudge do not seem to be toxic enough to afford effective results.

All spent compost as well as left over compost should be disposed of as quickly as possible and the doors and ventilators of the mushroom house screened with 30-mesh copper wire cloth, to prevent reinfestation once a house has gone through the heat and has been fumigated. Cheesecloth can be used to screen the doors and ventilators but copper wire cloth is more durable and perhaps the cheapest in the long run. (*Author's abstract.*)

A number of slides were shown. This paper was discussed by McINDOO, GRAF, BISHOPP, HOWARD BALDUF, and BRIDWELL.

(*To be continued.*)

SCIENTIFIC NOTES AND NEWS

Mrs. AGNES CHASE, of the Grass Herbarium, has returned from 7 months in Brazil. On this, her second visit to Brazil, Mrs. Chase collected grasses in the states of Rio de Janeiro, Espirito Santo, Minas Geraes, Goyaz, Sao Paulo, and Matto Grosso, going west to the boundary of Bolivia and south to near the boundary of Paraguay. In the two visits Mrs. Chase has made the largest collection of grasses ever obtained in Brazil, including many extensions of range and additions to the known flora of the country.

Dr. A. S. HITCHCOCK sailed for Europe August 1, to attend the International Botanical Congress at Cambridge, England. Dr. Hitchcock attends the Congress as delegate from the U. S. Department of Agriculture, the Botanical Society of America and the Botanical Society of Washington.

R. C. WELLS has been appointed chief chemist in charge of the Division of Chemistry and Physics, Geologic Branch, U. S. Geological Survey, and GEORGE STEIGER, former chief, will return to studies in chemical and spectroscopic analysis.

EUGENE CALLAGHAN, PERRY A. DAVISON, EDWIN B. ECKEL, CHARLES L. GAZIN, E. N. GODDARD, CHARLES B. HUNT, BERNARD N. MOORE, WATSON H. MONROE, CHARLES F. PARK, JR., WILLIAM S. PIKE, JR., GEORGE F. TAYLOR, and AARON G. WATERS have been appointed junior geologists; and LLOYD G. HENBEST, J. HARLAN JOHNSON, MAXWELL M. KNECHTEL, ALBERT H. KOSCHMANN, ROBERT E. LANDON, CHARLES B. READ, PHILIP J. SHENON, RALPH B. STEWART, and J. STEELE WILLIAMS, assistant geologists in the Geologic Branch, U. S. Geological Survey. RALPH W. RICHARDS has been reinstated as Geologist.